

भारतीय मानक

(Reaffirmed 2018)

जल वैज्ञानिक संरचनाओं तथा मशीनों पर भूकंप के अलावा  
कंपन अध्ययनों के लिये यंत्रों का संस्थापन, अनुसरण और  
अवलोकन — कार्य संहिता  
( पहला पुनरीक्षण )

*Indian Standard*

INSTALLATION, MAINTENANCE AND OBSERVATION  
OF THE INSTRUMENTS FOR VIBRATION STUDIES  
OTHER THAN EARTHQUAKES ON HYDRAULIC  
STRUCTURES AND MACHINES — CODE OF PRACTICE

( *First Revision* )

ICS 17.160; 93.160

© BIS 2013

**BUREAU OF INDIAN STANDARDS**  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

## FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hydraulic Structures Instrumentation Sectional Committee had been approved by the Water Resources Division Council.

Vibration refers to the mechanical oscillations about an equilibrium point. The oscillations may be periodic or random. The vibrations may be measured as displacement, velocity or acceleration with the help of displacement gauges, velocity pick-ups and accelerometers respectively. Displacement measurements require a stable reference structure close to the vibrating structure and it may be many a times impracticable to have one especially for hydraulic structures. Velocity pick-ups suffer from poor response to high frequency vibrations and are bulky for certain applications. The accelerometers hence are the most preferred. They are proven in respect of versatility, ruggedness, accuracy and dynamic response. Accelerometers employ piezoelectric elements, force balance techniques or strain gauge based elements. Therefore, the signal conditioners suitable for the particular type of accelerometers have to be provided. For the purpose of recording and analysis of data, a computerized signal analyzer with sufficient disk storage capacity completely replaces the earlier techniques of recording on multi-channel instrumentation tape recorders and analyzing on a tunable band pass filter type frequency analyzers. Battery operated signal analyzers are common now-a-days.

This standard covers requirements of the accelerometers, signal conditioning and signal processing equipment for the application of vibration studies.

This standard was first published in 2000 however, the Committee responsible for the formulation of this standard decided to revise it based on the experience gained since then as well as considering technological development in the field. New clause for safety criteria has also been incorporated in this standard.

The composition of the Committee responsible for the formulation of this standard is given at Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

## *Indian Standard*

# INSTALLATION, MAINTENANCE AND OBSERVATION OF THE INSTRUMENTS FOR VIBRATION STUDIES OTHER THAN EARTHQUAKES ON HYDRAULIC STRUCTURES AND MACHINES — CODE OF PRACTICE

( *First Revision* )

## 1 SCOPE

**1.1** This standard recommends instruments essential for observation of vibrations arising from hydraulic structures and machines. Vibration studies are conducted on hydraulic machines namely pumps, hydro-turbines, on civil structures namely dams, divide walls, bridges, power houses, foundations and on other parts namely gates, penstocks, trash-racks, etc. It further covers the details on installation of accelerometers and procedure for observations of the vibration with the help of associated instrumentation containing signal conditioner and signal processor.

**1.2** Vibration due to earthquake is beyond the scope of this standard.

## 2 REFERENCE

The standard listed below contain provisions which through reference in this text constitute provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision and parties to agreements based on this standard is encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

| <i>IS No.</i> | <i>Title</i>                                       |
|---------------|----------------------------------------------------|
| 14881 : 2001  | Method for blast vibration monitoring – Guidelines |

## 3 INSTRUMENTATION

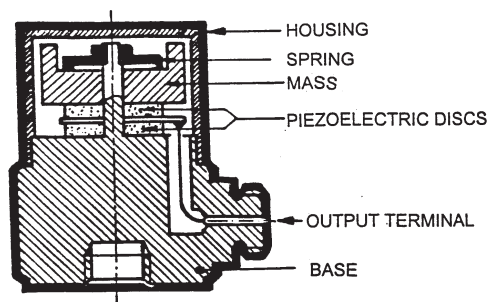
### 3.1 Accelerometers

#### 3.1.1 Selection

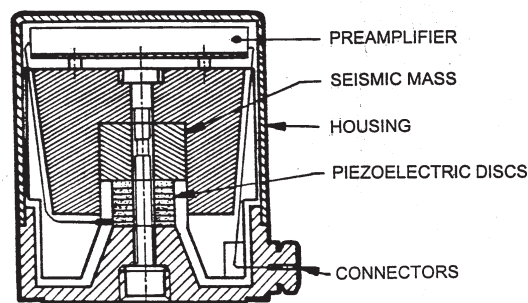
Accelerometers are designed to measure vibration over a given frequency range. Once the particular frequencies of interest for a machine are known, an accelerometer may be selected. Typically, an accelerometer for measuring machine vibration shall have a frequency range from 1 or 2 Hz to 8 or 10 kHz.

#### 3.1.2 Constructional Details

There are number of technologies on which accelerometers are based, however the technology in a piezoelectric accelerometer is that an electrical charge is developed when subject to dynamic stresses. In a piezoelectric accelerometer, a heavy mass (seismic mass) pre-loaded by a shift spring, rests on the stack of piezoelectric discs. When the assembly is subjected to vibration the mass exerts a dynamic force on the disc which develops a variable charge proportional to force and hence to acceleration. Figure 1 shows constructional details of an accelerometer.



GENERAL PURPOSE ACCELEROMETER



HIGH SENSITIVITY ACCELEROMETER

FIG. 1 CONSTRUCTIONAL DETAILS OF  
ACCELERATOMETER

### 3.1.3 Performance Characteristics

#### 3.1.3.1 Sensitivity

A piezoelectric accelerometer is electrically analogous to a capacitor shunted by a high resistance and also a voltage source or a charge source. The piezoelectric accelerometer thus has two sensitivities namely, charge sensitivity and voltage sensitivity. The voltage sensitivity is expressed as mv/m/s and charge sensitivity as pc/m/s. These two are related by,

Voltage sensitivity =

$$\frac{\text{Charge sensitivity}}{\text{Accelerometer capacitance} + \text{Cable capacitance}}$$

The charge output of accelerometer is independent of cable length, however the voltage output depends upon the cable length. Therefore, the charge output is preferred and hence the amplifier associated with piezoelectric accelerometer is invariably a charge amplifier. Accelerometer sensitivity is generally of the order of 10 pc/m/s.

#### 3.1.3.2 Frequency response

The frequency response is defined as the variation of accelerometer signal with reference to frequency of a sinusoidal vibration. The accelerometer signal is fairly constant over the desired frequency range. The natural resonance frequency of an accelerometer corresponds with natural frequency of the seismic mass. Up to a frequency of 1/5th of the natural resonance frequency the variation in accelerometer signal is generally within 6 percent.

On the lower end of the frequency spectrum rather than accelerometer the charge amplifier's frequency response becomes the limiting factor. The phase response is one of the significant characteristics in respect of transient and shock performance of the accelerometer. The upper frequency limitation should be at least 1 000 Hz.

#### 3.1.3.3 Dynamic range

The dynamic range is the range of magnitudes of accelerations over which the accelerometer output is directly proportional to the acceleration amplitude applied. The lower magnitude is limited by the mounting, cable length, environmental conditions and amplifier noise level. The higher magnitude for continuous accelerations is much higher than the accelerations encountered in practice.

#### 3.1.3.4 Sensitivity of accelerometers to unwanted parameters

The accelerometers are also sensitive to many other unwanted physical parameters namely temperature, sound, strain at the base surface, magnetism and transverse accelerations. These sensitivities cause error in measurements. The acceptable sensitivities on these accounts are as follows:

|                            |                                          |
|----------------------------|------------------------------------------|
| Temperature sensitivity    | : 1 pc/°C                                |
| Acoustic sensitivity       | : 0.01 pc at 154 db sound pressure level |
| Surface strain sensitivity | : 0.03 pc/microstrain                    |
| Magnetic sensitivity       | : 10 pc/Tesla magnetism                  |
| Transverse sensitivity     | : 4 percent                              |

### 3.2 Signal Conditioner

#### 3.2.1 Configurational Details

The signal conditioner comprises of electronic circuits comprising of the pre-amplifier as charge amplifier, low pass-high pass filters runs, integrators and peak detectors, etc. These circuits are built around operational amplifiers. The frequency response and gains of amplifier, choice of acceleration, velocity and displacement are switch selectable. Signal conditioner is provided with meter indication for RMS, peak values and is powered through line supply or built in battery pack. Figure 2 shows schematic of a signal conditioner.

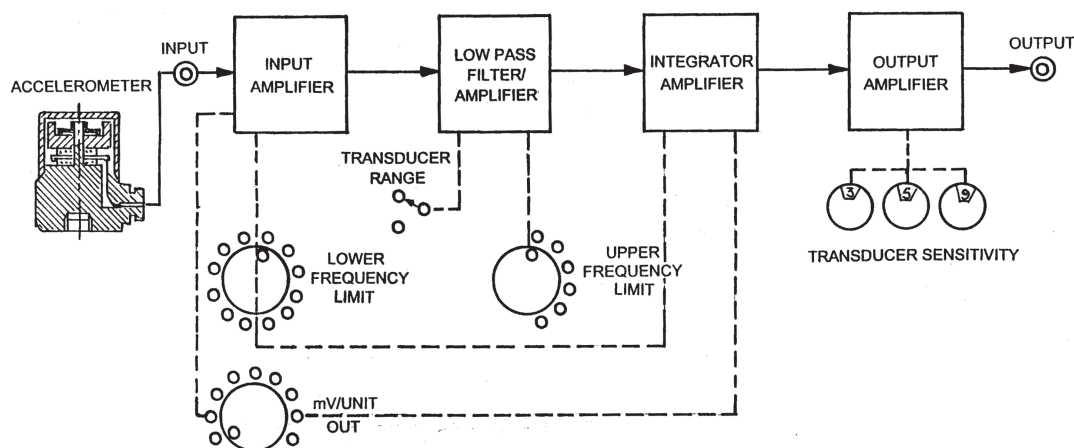


FIG. 2 PIEZOELECTRIC ACCELEROMETER AND SIGNAL CONDITIONER

### 3.2.2 Performance Characteristics

#### 3.2.2.1 Amplification

The gain of the amplifier is expressed in mv/pc and with 1 mv/pc gain termed as 0 db, amplifier with gain variation of the order of 100 db is required.

#### 3.2.2.2 Frequency response

The frequency response of the signal conditioner is adjusted by means of the low pass and high pass filter associated with the amplifier. The low frequency cut-off at minimum 0.2 Hz and high frequency cut-off at minimum 1 000 Hz or beyond is required for the applications. The filter roll off, of the order of minimum 12 db/octave is required for sufficient rejection of unwanted frequencies.

#### 3.2.2.3 Integration

The output of pre-amplifier corresponding to acceleration is integrated to produce output corresponding to velocity which when integrated in turn produces output corresponding to displacement. These integrators are, in fact, a pair of -20 db/octave cut-off low pass filters so that they produce outputs exactly corresponding to velocity and displacement. These filters are built around operational amplifier as active filter for good accuracies.

#### 3.2.2.4 Meter indication

The signal conditioner should be provided with panel meter indication of the vibration parameters for on-line monitoring and would also be helpful for setting up of instruments for experiments involving analyzers. The meter indication is both RMS and peak value selectable. The crest factor for RMS detector should be less than 3 and the time constant for the RMS as well as peak detector should be in the range of 1 to 10 s.

#### 3.2.2.5 Dynamic range

The amplifier gain should be switch selectable, each setting corresponding to combination of range and

sensitivity. The dynamic range would be most affected by noise level at the low end for the maximum sensitivity. A dynamic range of the order of minimum 50 dB would be required.

### 3.3 Signal Processor

#### 3.3.1 Evolution

The aim of vibration measurements should be to assess peak or RMS value of the vibration parameters and the frequency at which they occur. Since the vibration phenomenon would be random in nature to assess, its measurement needs to be carried out and measurement data analyzed on line. The earlier vibration measuring equipment contained an electronic tunable band pass filter and frequency spectrum strip chart recorder connected to the accelerometer and the signal conditioner. The signal conditioner with meter indication still prevails owing to suitability for routine monitoring applications. However, the electronic band pass filter and frequency spectrum recorder have now been replaced by computerized signal processor equipment. This standard elaborates only the signal processor, being relevant today.

#### 3.3.2 Configurational Details

The signal processor is an microcomputer based equipment. It essentially consists of analog input section, CPU, CRT display, floppy drives and output section and keys to perform various functions under microprocessor control. The microcomputer with the help of stored programmes and functional keys controls the operation of the equipment besides conducting the signal processing. A multi-channel inputs two or four channel versions with multiple display is required for the application. Figure 3 shows schematic of a signal processor.

The recorder should have a filter for cancellation of electrical noise which is common in most power plants and at blasting sites. The recorder should have RS-232 port for data transfer.

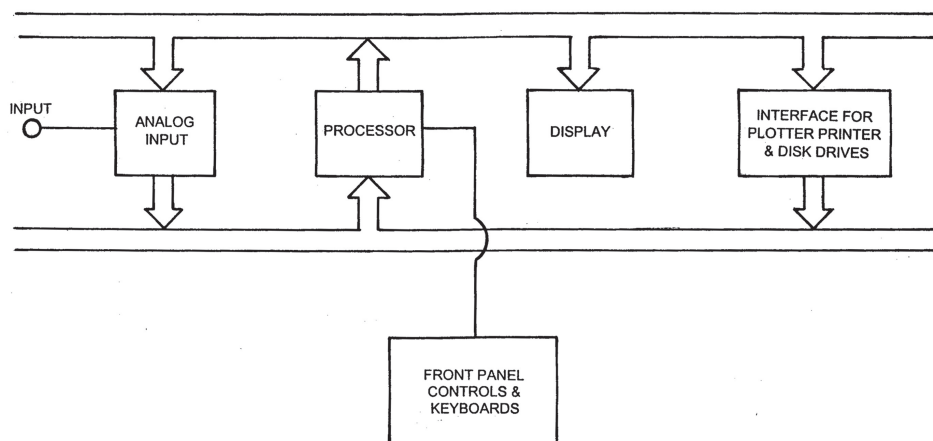


FIG. 3 SCHEMATIC OF SIGNAL PROCESSOR

### 3.3.3 Performance Characteristics

#### 3.3.3.1 Analog input characteristics

A multi-channel (two or four channels), direct coupled inputs for simultaneous data acquisition is required. The inputs are direct coupled so that the lowest frequency in the measured vibrations are not limited. The input impedance of the order of mega ohms or greater and frequency response beyond 1 000 Hz is required for the applications. The input section needs to contain an antialiasing filter with facility for selection of cut-off frequency with keys.

#### 3.3.3.2 Analysis functions

The following analysis functions are often required in vibration assessment work:

- a) Amplitudes and peaks in time domain.
- b) Instantaneous and average frequency spectrum, cross spectrum, coherence, transfer function, power spectral density.
- c) Orbits, nyquist diagrams, probability density functions, auto-correlation, cross-correlation, time averaging.
- d) Arithmetic and calculus functions.

#### 3.3.3.3 Other processing facilities

- a) Weighting functions for frequency spectrum.
- b) Transient capture and storage with preset delays.
- c) Selection of frequency range and amplitude range.
- d) Display formatting with markers, cursors, text editing, etc.
- e) Manual control by keyboard and disk data processing.

#### 3.3.3.4 Storage and presentation of results

The results of processing available on CRT display should be stored on floppy diskettes/hard disk and should be presented on a plotter or printer.

## 4 POINTS OF VIBRATION MEASUREMENTS

The vibration measurements are not always possible on the most pertinent parts namely runner blades or wicket gates of a hydro-turbine, bearings in rotating parts or flapper of a valve, etc. Therefore, bearing housing, valve body, etc, are considered measurement points. For measurement of gate vibrations and penstock vibrations, the accelerometers are installed directly on them for example, on a centrally placed girder of the gate. For vibrations measurement on bridges, bridge piers, power houses, divide walls, etc,

the points selected are generally at the centre of the walls, centre of girders, unsupported ends, etc, regardless of response of the structure to periodic or random stimuli. For vibration measurements on gravity dams, the points selected generally are along the crest of the dam, inside galleries at suitable elevation. However, an approximate estimate of the response of the structure helps in deciding the points of measurement.

## 5 INSTALLATION METHODS

### 5.1 Mounting Methods for Accelerometers

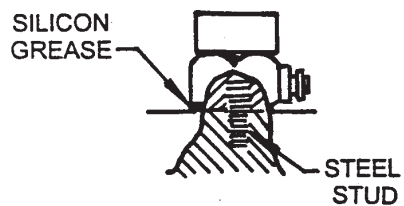
The mounting of an accelerometer affects its frequency response. The mounted natural frequency is dependent directly on the mounting. The higher the stiffness, the more the mounted natural frequency approaches its maximum. The least stiff mounting accelerometer is magnetic mounting and the highest stiffness is using a high tensile setscrew tightened to the flat surface. Other mounting methods come in between these two extremes. Stud mounting, quick fit mounting, adhesive mounting, magnetic mounting, mounting with wax are commonly used methods of mounting.

#### 5.1.1 Adhesive Mounting

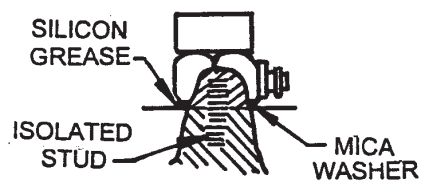
The simplest method of accelerometer mounting is by sticking it to the object with the help of double sided adhesive disk or bees wax. It is important to ensure that the site chosen for the accelerometer is ground flat for at least an area larger than the base of the slight smear of silicone grease which shall ensure a stiff bond between accelerometer and structure. Due to softening of the adhesive the contact of accelerometer with the object may be detached and also the adhesive method of mounting needs smooth, clean, oil-free surface of the object which may not always be available.

#### 5.1.2 Mounting Threads

The secure most mounting is possible by threading the accelerometer to the test object. The accelerometer manufacturers always provide them with a threaded hole at the base and accessories such as mounting studs or mounting magnets with matching threaded protrusions at the top. For installations on metallic object mounting with the help of magnets would suffice. The vibrations in two (X, Y) or three directions (X, Y, Z) at point are to be measured either with a three directional accelerometer or by threading three unidirectional accelerometers on a mild steel cube welded to the part. For measurements on concrete parts a mild steel piece with threaded hole is grouted into the concrete with the help of foundation bolts and the accelerometers are mounted by means of studs. Figure 4 shows mounting methods for accelerometers.



STUD MOUNTING



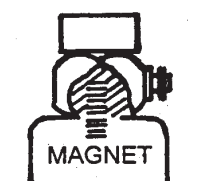
ISOLATED STUD MOUNTING



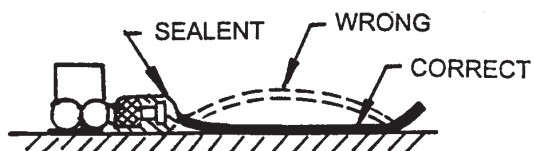
MOUNTING WITH WAX



MOUNTING WITH ADHESIVE DISC



MAGNET MOUNTING



CLAMPING ACCELEROMETER CABLE TO MINIMISE NOISE

FIG. 4 METHODS OF ACCELEROMETER INSTALLATION

### 5.1.3 Water-Proofing of a Mounting

In case the point selected is underwater or is likely to be subjected to splashes of water, the accelerometer mounting needs to be made waterproof with a waterproof housing onto it, through which the connecting cables are taken out. Figure 5 shows a recommended arrangement for the purpose.

## 5.2 Equipment Locations and Cable Layouts

The signal conditioner/amplifier, signal processor, plotter/printer should be kept in an enclosed shed having mains power connections, from which cables should be laid up to the measurement point. The laying out cable plays an important part in the accelerometer mountings as cable whips contribute to error in measurements arising from introduction of unwanted electrical inputs into the signal conditioning amplifier. The connecting cable should therefore be kept attached to the test objects end, and as far as possible not let free so that whipping due to wind should be avoided, as shown in Fig. 4.

## 5.3 Maintenance

The accelerometer has no moving part subject to normal wear. Therefore, the output sensitivity does not require periodic adjustments to correct for wear.

An accelerometer has internal components which can be damaged from shock or overheating. When an accelerometer is suspect, a simple test of the transducer's bias voltage shall help determine whether it should be removed from service. An accelerometer's bias voltage is the d.c. component of the transducer's output signal. The bias voltage is measured with a d.c. voltmeter across the transducer's signal output and common leads with power applied. At the same time, the power supply voltage should also be checked to eliminate the possibility of improper power voltage affecting the bias voltage level.

## 6 EXPERIMENTAL DATA COLLECTION

### 6.1 Calibration

#### 6.1.1 Pre-Measurement Calibration

The accelerometer and amplifier performance characteristics are generally stable. These, however, should be checked even on site. This should be carried out by reciprocity method for accelerometer using a standard accelerometer, miniature vibration source and sensitivity comparator, and for charge amplifier by charge simulation method using a calibrator producing known charge and a digital voltmeter.

**6.1.2** Under normal conditions, piezoelectric sensors are extremely stable and their calibrated performance characteristics do not change over time. However, often

sensors are exposed to harsh environmental conditions, like mechanical shock, temperature changes, humidity, etc. Therefore a re-calibration cycle should be established.

**6.1.3** For applications where high accuracy is required, the accelerometer should be recalibrated every time after use under severe conditions or at least every 2 years.

## 6.2 Instrument Check-Up

Having completed the installation of accelerometers and having made electrical connections of the equipment before data collection, a thorough instrument check is very essential. Considering the sources of vibrations, these would be repetitive in nature and signal validity checks could be easily carried out during this phase. The following requires special attention:

- a) To ensure that the mains supply frequency (50 Hz pick-up, d.c. off-set and low frequency) variations should be minimum possible to an extent that does not affect measurement results.
- b) The sensitivity ranges should be selected to accommodate the signal within dynamic range of the instruments.

Figure 6 shows instrument set-up for vibration measurements.

## 6.3 Measurement Procedures

### 6.3.1 Measurement Conditions

The vibrations change according to various conditions to which the test part is subjected, for example gate openings, electrical load on machine. For each different condition the signal validity may be checked as mentioned in 6.2 for the procedure for instrument check-up.

### 6.3.2 Measurement Time

A portable signal processor conducts on-line analysis. However, the record time selection should be limited. The frequency range, the frequency resolution and record length are interrelated as follows:

$$T = 1/f_R,$$

where

$$\begin{aligned} T &= \text{record time; and} \\ f_R &= \text{frequency resolution} \\ &= (2.56 \times F_{\text{Max}}) / N_t; \end{aligned}$$

where

$$\begin{aligned} F_{\text{Max}} &= \text{maximum anticipated frequency of vibrations; and} \\ N_t &= \text{samples in time.} \end{aligned}$$

### 6.3.3 Recording Observations

The records of the measurements conducted should be kept in a tabular form. The table should bear at the head all the pertinent details for example, reservoir level, condition of gates, machine speed, head on machines, load, etc, and date and time of experiment. In case of simultaneous measurements on a number of channels, all the locations form the columns and measurement conditions form the rows. Many sub-conditions within a condition are possible for example, a load on hydro-turbine with other unit at different load conditions. It is possible that the readings are not taken simultaneously or in the order indicated by the table

due to operational constraints or equipment limitations, therefore each condition and sub-condition as well as the points of measurements may be dated and time marked.

Entries should be made in the record during observations for,

- actual parameters value while using indicating instrument; and
- file names, diskette identification numbers while using signal processor.

A typical vibration measurement record is given below:

Name of project :  
 Date :  
 Reservoir level :  
 Tail Race level :  
 Unit No. :  
 Gate opening :  
 Machine speed :

| MEASURE-<br>MENTS<br><br>POWER<br>GENERATION | TURBINE GUIDE<br>BEARING:<br>VERTICAL | TURBINE GUIDE<br>BEARING:<br>HORIZONTAL | GENERATOR<br>FLOOR BEARING:<br>VERTICAL | GENERATOR<br>THRUST BEARING:<br>HORIZONTAL | CONTROL ROOM<br>FLOOR:<br>VERTICAL | CONTROL ROOM<br>FLOOR:<br>HORIZONTAL |
|----------------------------------------------|---------------------------------------|-----------------------------------------|-----------------------------------------|--------------------------------------------|------------------------------------|--------------------------------------|
| 0 MW                                         |                                       |                                         |                                         |                                            |                                    |                                      |
| 10 MW                                        |                                       |                                         |                                         |                                            |                                    |                                      |
| 20 MW                                        |                                       |                                         |                                         |                                            |                                    |                                      |
| 30 MW                                        |                                       |                                         |                                         |                                            |                                    |                                      |
| 40 MW                                        |                                       |                                         |                                         |                                            |                                    |                                      |
| 50 MW                                        |                                       |                                         |                                         |                                            |                                    |                                      |

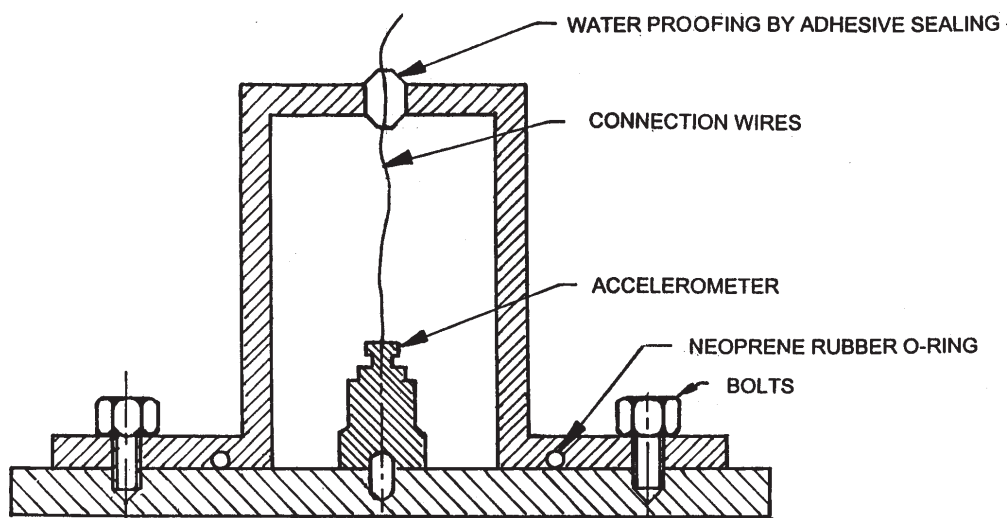


FIG. 5 WATER PROOF HOUSING FOR ACCELEROMETER

### 6.3.4 Safety Criteria

For evaluation of the safety criteria for the structural response to vibration (*see* IS 14881).

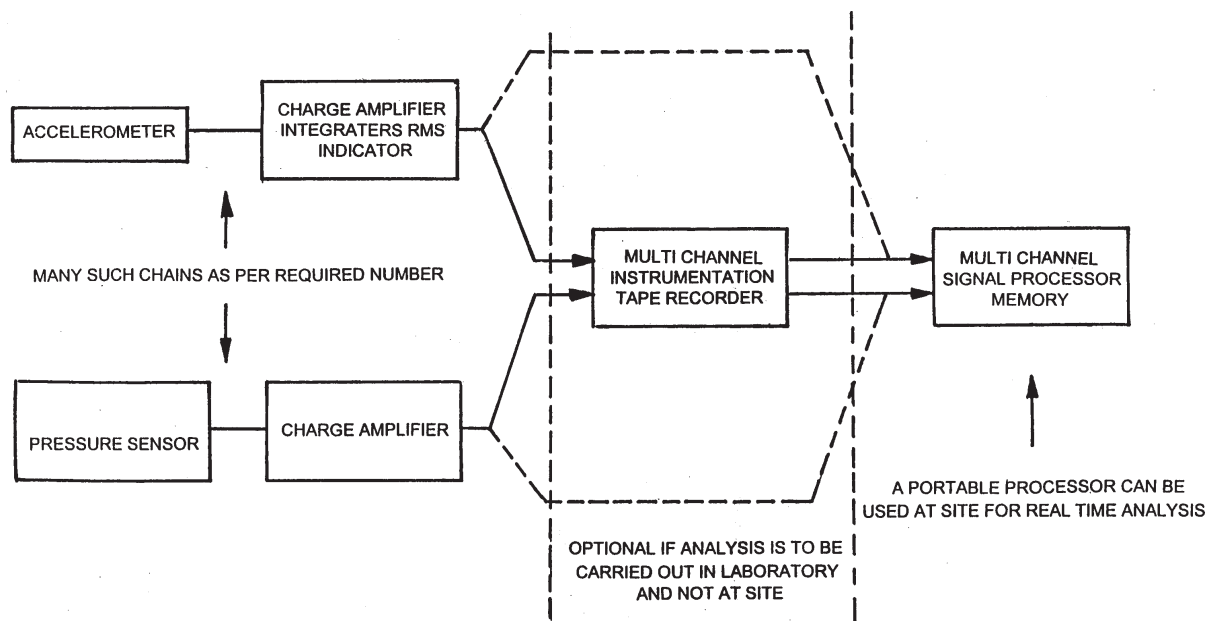


FIG. 6 INSTRUMENT SET-UP FOR VIBRATION AND PRESSURE PULSATION MEASUREMENTS

**ANNEX A***(Foreword)***COMMITTEE COMPOSITION****Hydraulic Structures Instrumentation Sectional Committee, WRD 16**

| <i>Organization</i>                                            | <i>Representative(s)</i>                                                                                             |
|----------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Central Soil & Materials Research Station, New Delhi           | SHRI MURARI RATNAM ( <b>Chairman</b> )                                                                               |
| AIMIL Ltd, New Delhi                                           | SHRI S. P. GUPTA<br>SHRI SANJAY KUMAR ( <i>Alternate</i> )                                                           |
| Andhra Pradesh Power Generation Corporation Limited, Hyderabad | SHRI D. SUDARSHAN                                                                                                    |
| Bhakra Beas Management Board, Nangal Township                  | DIRECTOR (DAM SAFETY)<br>EXECUTIVE ENGINEER ( <i>Alternate</i> )                                                     |
| Central Building Research Institute, Roorkee                   | SHRI AJAY CHAURSA<br>SHRI JALAJ PARASHAR ( <i>Alternate</i> )                                                        |
| Central Soil & Materials Research Station, New Delhi           | SHRI S. L. GUPTA<br>SHRI R. K. MATHUR ( <i>Alternate</i> )                                                           |
| Central Water & Power Research Station, Pune                   | SHRI S. G. CHAPHALKAR<br>SHRI R. ALI ( <i>Alternate</i> )                                                            |
| Central Water Commission, New Delhi                            | DIRECTOR (INSTRUMENTATION)<br>DIRECTOR EMBANKMENT (N&W) ( <i>Alternate</i> )                                         |
| Consulting Engineering Services (I) Ltd, New Delhi             | SHRI P. K. DATTA<br>SHRI R. S. DAS ( <i>Alternate</i> )                                                              |
| Damodar Valley Corporation Ltd, Bihar                          | CHIEF ENGINEER (CIVIL)<br>SUPERINTENDING ENGINEER (CIVIL) ( <i>Alternate</i> )                                       |
| Encardio-Rite Electronics Pvt Ltd, Lucknow                     | SHRI AMOD GUJRAL<br>SHRI K. K. RAI ( <i>Alternate</i> )                                                              |
| IIT, Roorkee, Uttarakhand                                      | DR R. P. SINGH<br>DR NAYAN SHARMA ( <i>Alternate</i> )                                                               |
| Irrigation Department, Government of Andhra Pradesh, Hyderabad | SHRI M. ASHOK KUMAR<br>SHRI A. MANOJ KUMAR ( <i>Alternate</i> )                                                      |
| Irrigation Department, Government of Gujarat, Vadodara         | DIRECTOR                                                                                                             |
| Irrigation Department, Government of Maharashtra, Nasik        | RESEARCH OFFICER<br>ASSISTANT RESEARCH OFFICER ( <i>Alternate</i> )                                                  |
| Irrigation Department, Government of Punjab, Chandigarh        | CHIEF ENGINEER (Dam Design)                                                                                          |
| Irrigation Research Institute, Roorkee                         | CHIEF ENGINEER DESIGN<br>SUPERINTENDING ENGINEER ( <i>Alternate</i> )                                                |
| Karnataka Power Corporation Ltd, Karnataka                     | CHIEF ENGINEER (CIVIL DESIGNS)<br>PROJECT ENGINEER DESIGNS ( <i>Alternate</i> )                                      |
| Kerala State Electricity Board, Kerala                         | SHRI PHILIP ZACHARIAH<br>EXECUTIVE ENGINEER ( <i>Alternate</i> )                                                     |
| NHPC Ltd, Faridabad                                            | SHRI A. K. JAIN<br>SHRI H. V. S. RUDRAPPA ( <i>Alternate</i> )                                                       |
| NTPC Limited, Noida, U.P.                                      | SHRI R. C. SENAN<br>SHRI MADHUKAR AGARWAL ( <i>Alternate</i> )                                                       |
| Pubic Works Deptt, Government of Tamil Nadu, Tamil Nadu        | EIC, WRO AND CE (G1)<br>SUPERINTENDING ENGINEER ( <i>Alternate</i> )                                                 |
| Satluj Jal Vidyut Nigam Limited, New Shimla                    | SHRI BRIJESH KUMAR GUPTA                                                                                             |
| Tamil Nadu Electricity Board, Chennai                          | SHRI V. SANTHANAKRISHNAN<br>SHRI S. SIVAKUMAR ( <i>Alternate</i> I)<br>SHRI V. GOPALAKRISHNAN ( <i>Alternate</i> II) |
| Uttarakhand Jal Vidyut Nigam Limited, Dehradun                 | SHRI VYAS DEV AJMANI<br>SHRI N. K. MAHESHWARI ( <i>Alternate</i> )                                                   |

## IS 14793 : 2013

### *Organization*

Vasi Shums & Co Private Ltd, Mumbai

In personal capacity (C-3/3188 Vasant Kunj, New Delhi 110070)

BIS Directorate General

### *Representative(s)*

SHRI Z. M. KARACHIWALA

DR A. K. DHAWAN

SHRI J. C. ARORA, Scientist 'F' & Head (WRD)

[Representing Director General (*Ex-officio*)]

### *Member Secretary*

Shri R. R. DASH

Scientist 'C' (WRD), BIS

## Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

## Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

## Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

This Indian Standard has been developed from Doc No.: WRD 16 (503).

### Amendments Issued Since Publication

| Amend No. | Date of Issue | Text Affected |
|-----------|---------------|---------------|
|           |               |               |
|           |               |               |
|           |               |               |
|           |               |               |

### BUREAU OF INDIAN STANDARDS

#### Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002

Telephones : 2323 0131, 2323 3375, 2323 9402

Website: [www.bis.org.in](http://www.bis.org.in)

#### Regional Offices:

Telephones

|          |                                                                          |                                                |
|----------|--------------------------------------------------------------------------|------------------------------------------------|
| Central  | : Manak Bhavan, 9 Bahadur Shah Zafar Marg<br>NEW DELHI 110002            | { 2323 7617<br>2323 3841                       |
| Eastern  | : 1/14 C.I.T. Scheme VII M, V. I. P. Road, Kankurgachi<br>KOLKATA 700054 | { 2337 8499, 2337 8561<br>2337 8626, 2337 9120 |
| Northern | : SCO 335-336, Sector 34-A, CHANDIGARH 160022                            | { 260 3843<br>260 9285                         |
| Southern | : C.I.T. Campus, IV Cross Road, CHENNAI 600113                           | { 2254 1216, 2254 1442<br>2254 2519, 2254 2315 |
| Western  | : Manakalaya, E9 MIDC, Marol, Andheri (East)<br>MUMBAI 400093            | { 2832 9295, 2832 7858<br>2832 7891, 2832 7892 |

**Branches:** AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. DEHRADUN. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISAKHAPATNAM.

Published by BIS, New Delhi